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Impacts of Floods on Nyabugogo River Bed in Kigali City, Rwanda

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Abstract

This study aims to assess the impacts of floods on Nyabugogo river bed in Kigali City of Rwanda, East Africa. The employed secondary data were obtained through desk review, and the primary data were collected throughout site visit for the observations and surveys techniques to record the width and bottom elevations of Nyabugogo river. These data were obtained through topographic survey equipment at six selected stations on Nyabugogo river. The data were processed and analyzed by using the Statistical Package for Social Sciences (SPSS) and Microsoft Excel. The period of this study was basically two years between January 2019 and January 2021. The results showed that the impacts associated with floods on Nyabugogo river are the excessive river width from riverbanks sliding and bottom levels changes resulted from sediments deposition. It was noted that the changes in river width were between 1.980 m and 6.85 m, while the bottom river elevation was decreased at 0.62m at station 2 only. The maximum bottom level increase of 1.54 m was observed at station 5. Despite the fact that it might not be easy for the government to stop flooding at Nyabugogo river, it is good to replant bamboo trees and grasses in the areas that they are missing along Nyabugogo river to protect soil erosion and river bank sliding. Placing the gabions at some locations of Nyabugogo river reaches is required in order create a good river landscape in Kigali City. Also, it is suggested to prepare and provide training and awareness programs on environmental matters on surrounding residents. This would help to reduce discharge household wastes in Nyabugogo river and its effluents in order to minimize bottom rivers sediments deposit which results in excessive floods. Finally, respect and protect buffer-zone along Nyabugogo river to enhance soil resistance to flood. The long-term solution should be to educate children and young people the course of waste management at schools as a solution to environmental pollution.

Keywords

Impact, Floods, Nyabugogo River, Kigali City, Rwanda

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1. Introduction

Many Low income developing countries, particularly small countries, are vulnerable to natural disasters that can have large human, economic, and social costs. Recent examples of major disasters include Cyclone Idai (March, 2019), which caused significant loss of life and widespread economic disruption in Mozambique and neighbouring countries, and Hurricane Maria (September 2017), which caused damage to people's property and infrastructure estimated at some 200 per cent of GDP in Dominica. As the frequency and intensity of natural disasters is projected to increase over time with climate change, the economic and social negative impacts of disasters can also be expected to increase relatively [7].

A variety of climatic and non-climatic processes influence flood processes, resulting in river floods, flash floods, urban

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floods, sewer floods, as well as glacial lake outburst floods. Human encroachment into flood plains and lack of flood response and control plans increase the damage potential [12].

In Rwanda, 16% to 40% of the land is steep slope easily exposed to soil erosion which causes approximately an annual loss of 1.4 million tons of fertile soil. This implies a high nutrients demand, (around 50% of all soils), due to a high level of erosion and acidity of residual soil [8].

Furthermore, in May 3, 2020 Meteo Rwanda through Ministry of Environment, revealed that more heavy rain was expected in Kigali city, Northern Province and Rubavu, Nyabihu, Rutsiro, Ngororero, Muhanga and Ruhango districts over the next 7 days, increasing the risk of further floods and landslides [11]. Thereafter, The Ministry of Emergency Management (MINEMA) reported that heavy rain fell across the country from 01 May causing severe damages. During the month of May 2020 many disaster incidents occurred across the country, where on 03 May 8 people had died, 5 were injured, more than 100 houses had collapsed and roads were closed. Therefore people urged to take necessary precaution [4]. On February 11, 2020, The NewTimes reported that for many years, Nyabugogo river flooding has claimed people's lives, damaged properties and led to business losses. They added that the recent downpour alone killed people, paralysed business and halted transport in areas such as Nyabugogo [14].

Figure 1. Nyabugogo bridge after a heavy rain on January 26, 2020, Source: NewTimes.

During the month of January, 2020, rainfall amount recorded over Rwanda was ranging between 48.6mm and 222.4mm. The central region represented by Gitega and Kigali Aeroport weather stations of Kigali city recorded 166.4mm and 128mm respectively [10].

Flooding events occur up to three times per year in the Nyabugogo wetlands and affect the wetlands along the area of the maturation ponds, from the Nyabugogo International Bus Terminals, located on the eastern edge of the Kigali-Muhanga. This highway is a main thoroughfare used intensively by cars, motorcycles, busses, trucks, bicycles and pedestrians entering and leaving Kigali [3].

On the dates of 6th and 7th December 2019, extensive floods were happened along Nyabarongo river and its affluents in Ngororero district of Northern Province, damaging crops in Matyazo, Muhanda, Shyira and Kabaya sectors with maximum recorded rainfall at 60.8mm. Heavy rain continued to affect also central Regions of Rwanda (particularly in Kigali City and the Southern Provinces) over the past 72 hours, triggering floods and mudslides [19].

Since the beginning of November 2019, Rwanda has increasingly experienced heavy rains which have affected most parts of the country. As a result, many rivers across the country received huge levels of rainwater and overflew along their courses [6]. Furthermore, depending on the type and level of water pollution, the water body may become also unsuitable for fishing, swimming, or even for aquatic animals to survive in [1].

It has pointed out that the flooding occurred in Nyabugogo river and in its surrounding areas during rainy season are likely caused mainly by meanders at some Nyabugogo river reaches, which result in the floods which are not flash floods because they are likely to occur every year and for a long event. In addition, another cause of floods in the Nyabugogo wetlands is sediments deposition which decrease the river bed level [9].

The recent environmental studies have reported about the pollution of major Rwandese rivers such as Mpazi, Nyabarongo, Rusine, Muvumba and Nyabugogo. The results indicated that the presence of toxic pollutants such as heavy metals in water and fish poses health threats when they are consumed [18]. Therefore, heavy metals such as manganese, zinc, copper, iron, nickel, lead and cadmium, were reported in the edible parts of Colocasia esculenta, Amaranthus spinosus, Ipomoea batata and soils from industrially active parts of Kigali City, in Rwanda [2], [5].

Another study revealed that the quality of water and fish, particularly with respect to heavy metals from Nyabarongo and Nyabugogo rivers of Rwanda exceeded compliance guidelines and standards [17].

Though previous studies reported on Nyabarongo river catchment, none reported on the impact of flood on Nyabugogo river bed and banks. Based on river topographic survey data collection and analysis, this study reveals the impact of floods on Nyabugogo river banks in Kigali City from 2019 to 2021.

2. Methods and Materials

2.1. Description of the Study Area

The Nyabugogo River traverses the City of Kigali and has

many tributaries. The Nyabugogo wetland is located between 1354 m and 2,278 m above sea level and between 1094'S and 30004'E. The wetland drains a total area of 1,647 km^2 (Figure 2). Nyabugogo wetland is located within the Nyabugogo catchment and it covers both rural and urban areas including the city of Kigali, the capital city of Rwanda [9].

Nyabugogo wetland cuts across two districts Nyarugenge and Gasabo with an estimated population of 825,767 inhabitants [16]. The wetland is part of the Nyabugogo catchment which cuts across Eastern Province (Kayonza, Rwamagana, and Gatsibo districts), and Northern Province Gicumbi and Rulindo and other districts of Kigali city such as Kicukiro, Nyarugenge, and Gasabo districts where the current study area is located. Its estimated population is about 1,135,428 inhabitants [16].

The Nyabugogo river, the main river crossing the wetland, has a total length of 42.69 km. This river has many tributaries such as Mwange, Rusine and Marenge river on its upstream portion. It is also fed up other rivers from the urbanized part of Kigali, like Rwanzekuma, Ruganwa, Mpazi, and Yanze River [13].

The major land use activity in the catchment is agriculture that occupies about 897 km^2 (about 54%) of the catchment. Its climate is mostly of temperature ranging between 16°C and 23°C depending on the altitude of the area [15].

The annual rainfall in Rwanda varies from about 800 mm to 1,600 mm. There are normally four seasons in Rwanda. The first is a long dry season that spans from June to September, followed by a short rainy season spanning from October to December. This season receives 30% to 40% of the annual rainfall with the highest rains falling in November. The third is a short dry season starting in December and ending in January. The fourth is a rainy season spanning from February to end of May. This season receives around 60% of annual rainfall. The major possible pollution generating activities identified in the catchment include flower farming and the Kabuye sugar works which are both located along the Nyabugogo River, sugar cane plantation upstream, legumes and rice cultivation, quarrying and mining activities. There are many other industries concentrated in the Kigali industrial area that discharge all their liquid wastes into the Ruganwa River. The UTEXRWA textile industry also discharges its effluent into the Rwanzekuma River [15].

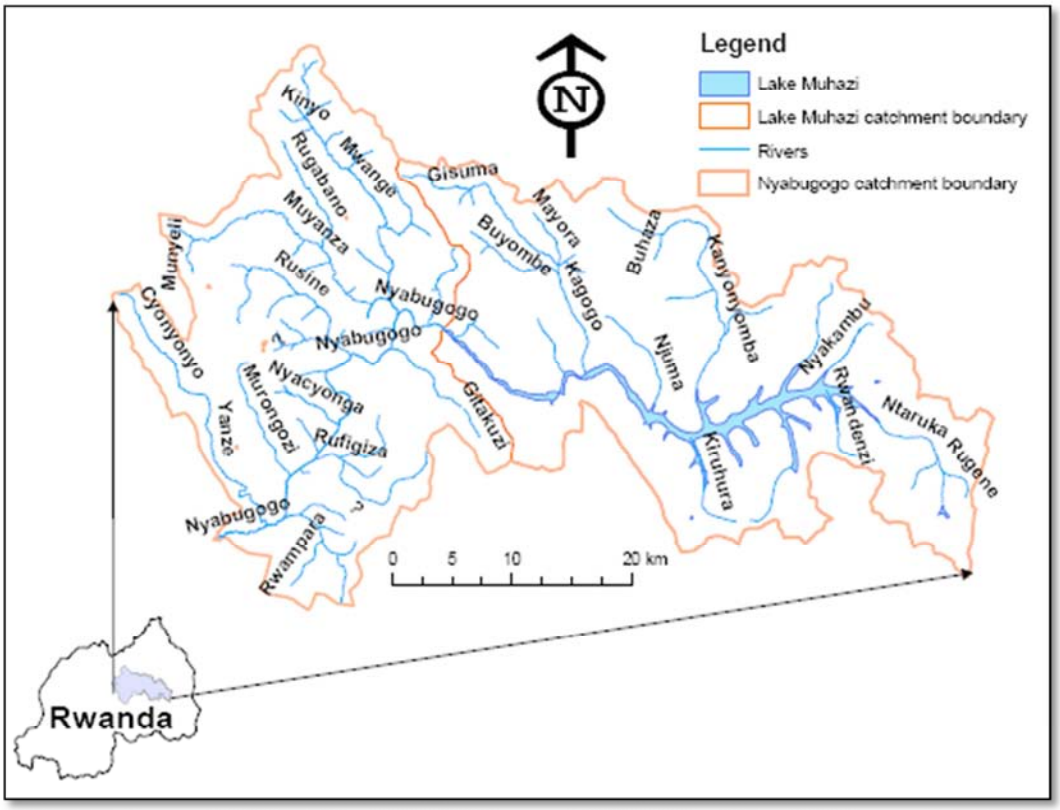

Figure 2. Map of Nyabugogo River catchment.

2.2. Location of Topographic Survey Stations

A total number of 6 survey stations (Figure 3) were selected for Nyabugogo river topographic survey. The rationale for choosing these sites was to ensure river bed and banks variations during the course of action.

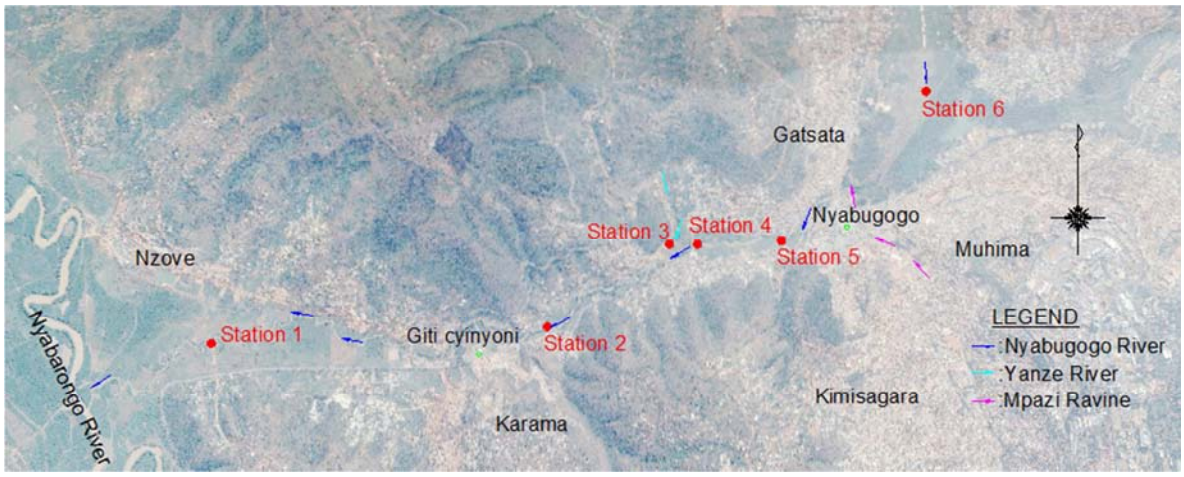

Figure 3. Map of topographic survey stations on Nyabugogo River.

Table 1. Location of study data collection stations at Nyabugogo River.

Sample Station	X (m)	Y (m)
1	166953.380	9784375.930
2	169190.110	9784479.260
3	170010.610	9785032.020
4	170177.420	9785033.540
5	170751.370	9785056.220
6	171703.600	9786041.100

Figure 4. Nyabugogo river survey 2021, Source: Author.

2.3. Data Collection and Analysis

The study used secondary and primary data. Secondary data were collected from desk review. The primary data were collected throughout site visit for the observations and surveys techniques, to record width and bottom elevation of Nyabugogo river. These data were obtained through topographic survey equipment at the six selected stations on Nyabugogo river. The figure 4 certifies the field data collection at Nyabugogo river.

Thereafter, the collected data were processed and analyzed by using the Statistical Package for Social Sciences (SPSS) and Microsoft Excel. The period of this study was basically two years between January 2019 and January 2021.

3. Results

3.1. Variation of Nyabugogo River Width

Table 2. Topographic Survey data on Nyabugogo river width.

Station	Jan. 2019 (m)	Jan. 2021 (m)	Increase (m)
1	18.82	25.66	6.838
2	19.49	25.03	5.540
3	5.25	12.10	6.850
4	11.24	16.02	4.780
5	14.00	19.81	5.810
6	10.72	12.70	1.980

The Topographic survey data presented in the Table 2 revealed that on the length of 1,500m of Nyabugogo river along six selected study stations, the minimum increase of river width is 1.980 m at station 6 and the maximum increase of Nyabugogo river width is 6.850m at station 3.

3.1.1. Statistical Analysis of River Width Data

Table 3. Paired Samples Statistics.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Sample 2	18.5530	6	5.93848	2.42437
	Sample 1	13.2533	6	5.38453	2.19823

Table 4. Paired Samples Correlations.

		N	Correlation	Sig.
Pair 1	Sample 2 & Sample 1	6	0.954	0.003

Table 5. Paired Samples Test.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Sample 2 - Sample 1	5.29967	1.80989	0.73888	3.40031	7.19903	7.173	5	0.001

3.1.2. Interpretation of Nyabugogo River Width Data Analysis Results

H_o = There is no significant increase of Nyabugogo river width between 2019 and 2021sample data

H_1 = There is a significant increase of Nyabugogo river width between 2019 and 2021sample data

SPSS; t_{calc} = 7.173 and $t_{tabulated}$ = 2.5706

Degree of freedom (df) = 5

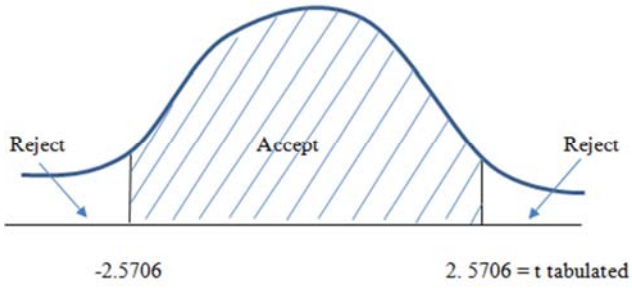

Figure 5. Rejection region.

Decisions based on data analysis:

tcalc > t tab; 7.173 > 2.5706

Therefore, Ho is rejected.

r =1 =perfect

0.75 ≤ r< 1; very high

0.50≤ r< 0.75; high

0.25≤ r< 0.50; low

0< r< 0.75; very low

r=0 = no correlation

Therefore, the correlation coefficient "r" is 0.954, which is very high correlation.

Hence, Ho is rejected.

P value < α

α= 0.05

0.001 < 0.05

P value < α

H_o is rejected and H1 is accepted

This means that there is a significant increase of Nyabugogo river width between 2019 and 2021.

P-value is less than alpha (0.05) (0.001 < 0.05).

0.75 ≤ r< 1; there is very high increase of Nyabugogo river width from January 2019 to January 2021, as the correlation coefficient " r" is 0.954.

3.2. Nyabugogo River Bottom Elevation

Table 6. Survey data on Nyabugogo river bottom elevation.

Station	Jan. 2019 (m)	Jan. 2021 (m)	Increase (m)
1	1345.57	1346.11	0.540
2	1351.68	1351.06	-0.620
3	1354.83	1355.54	0.710
4	1353.64	1354.01	0.370
5	1354.15	1355.69	1.540
6	1357.81	1358.84	1.030

The data presented in Table 2 showed that the depth of Nyabugogo river increased 0.620 m at station 2. It was decreased 1.540 m at station 5. This represents the accumulation of bottom river sediments.

3.2.1. Statistical Analysis of Nyabugogo River Bottom Elevation Data

Table 7. Paired Samples Statistics.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Sample 2	1.3535E3	6	4.43370	1.81005
	Sample 1	1.3529E3	6	4.12668	1.68471

Table 8. Paired Samples Correlations.

		N	Correlation	Sig.
Pair 1	Sample 2 & Sample 1	6	0.988	0.000

Table 9. Paired Samples Test.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Sample 2 - Sample 1	0.59500	0.72462	0.29582	-0.16544	1.35544	2.011	5	0.100

3.2.2. Interpretation of River Bottom Elevation Data Analysis Results

H_o = There is no significant increase of Nyabugogo river bottom sediments between 2019 and 2021

H_1 = There is a significant increase of Nyabugogo river bottom sediments between 2019 and 2021

SPSS; $t_{calc} = 2.011$ and $t_{tabulated} = 2.5706$

Degree of freedom (df) = 5

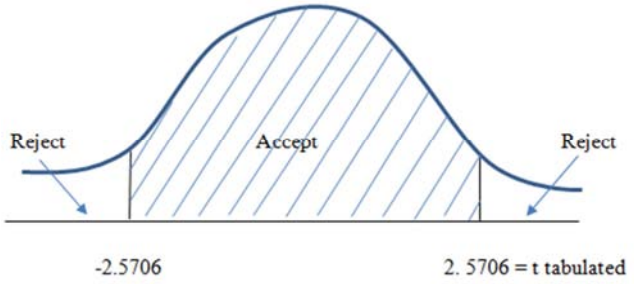

Figure 6. Rejection region.

Decisions based on data analysis:

When tcalc > t tab; Ho is rejected.

Therefore, 2.011 < 2.5706, so, Ho is accepted.

H_o = There is no significant increase of Nyabugogo river bottom sediments between 2019 and 2021.

r =1 =perfect

$0.75 \leq r < 1$; very high

$0.50 \leq r < 0.75$; high

$0.25 \leq r < 0.50$; low

$0 < r < 0.75$; very low

r=0 = no correlation

Therefore, the correlation coefficient "r" is 0.988, which is very high.

If, P value < α, H_o is rejected and H1 is accepted

α= 0.05

0.100 > 0.05

P value > α

H_o is accepted and H1 is rejected.

This means that there is no significant increase of Nyabugogo river bottom sediments between 2019 and 2021.

P-value is more than alpha (0.05) (0.100> 0.05).

$0.75 \leq r < 1$; there is very high increase of Nabugogo river bottom sediments from January 2019 to January 2021, as the correlation coefficient " r" is 0.988, but at 0.000 significance level.

3.3. Nyabugogo River Width and Bottom Elevation Changes

Table 10. Illustration of Nyabugogo river width and bottom elevation changes.

Changes in Nyabugogo river width				Changes in Nyabugogo river bottom level		
Station	**Jan. 2019 (m)**	**Jan. 2021 (m)**	**Increase (m)**	**Jan. 2019 (m)**	**Jan. 2021 (m)**	**Increase (m)**
1	18.82	25.66	6.838	1,345.57	1,346.11	0.540
2	19.49	25.03	5.540	1,351.68	1,351.06	-0.620
3	5.25	12.10	6.850	1,354.83	1,355.54	0.710
4	11.24	16.02	4.780	1,353.64	1,354.01	0.370
5	14.00	19.81	5.810	1,354.15	1,355.69	1.540
6	10.72	12.70	1.980	1,357.81	1,358.84	1.030

Considering the results in Table 10, the decrease of Nyabugogo river bottom levels is not directly influencing the widening of the river bed. At the station 5, there was a maximum decrease of Nyabugogo bottom level was 1.54 m, and river width increased 5.81m. While at station 3, the decrease of Nyabugogo river bottom levels was 0.71m and the width increased 6.85m which is the maximum width result in this study.

4. Discussions

In 2019, The International Monetary Fund predicted that as the frequency and intensity of natural disasters is projected to increase over time with climate change, the economic and social negative impacts of disasters can also be expected to increase relatively [7]. The main objective of this study was to assess the impacts of floods on Nyabugogo river bed, in Kigali City. The results show that minimum increase of river width is 1.980 m at station 6 and the maximum increase of river width is 6.850 m at station 3 for the period of 2 years (2019- 2021).

The literature stated that a variety of climatic and non-climatic processes influence flood processes in Nyabugogo river [12]. Those processes are caused mainly by meanders in Nyabugogo river and its surroundings areas during rainy season, and the sediments deposition which decreases the river bed level [9]. Although this study confirms the former authors findings, its results show that the rivers bed decrease

does not influence itself the river banks sliding or river widening as shown in Table 10, without considering the soils characteristics which were not covered by this study.

The increase deposit of sediments in the bottom of Nyabugogo river should be the source of the negative impacts that the quality of water and fish, particularly with respect to heavy metals from Nyabarongo and Nyabugogo rivers of Rwanda exceeded compliance guidelines and standards [17]. This impact should in the long run reflect the disturbance of ecosystem in Nyabarongo river which is the discharge point of Nyabugogo river.

The likely negative impacts should be considered in Nyabugogo river tributaries in Kigali City such as Mpazi, Yanze, and Nyacyonga where there is a presence of toxic pollutants such as heavy metals like manganese, zinc, copper, iron, nickel, lead and cadmium, which were reported in the edible parts of Colocasia esculenta, Amaranthus spinosus, Ipomoea batata and soils from industrially active parts of Kigali [18], [2], [5].

It was argued that Nyabugogo river widening trends to impact negatively the socio-economic livelihood of neighbouring households. Ecologically, this study agreed with the findings from the study stated that there should be an implication of a high nutrients demand, due to a high level of erosion and acidity of residual soil in Kigali City [8]. Nyabugogo river banks sliding increase soil erosion in Nyabugogo marshland and contribute excessively to surface water pollution by increasing turbidity level and suspended solid in Nyabugogo water course.

5. Conclusion

The results of this study lead to the conclusion that the floods impact on Nyabugogo river bed by increasing river width and contribute more on river bottom level fluctuations at some river reaches. The factors associated with excessive river width are mainly type of soil and soil characteristics. Despite the fact that it might not be easy for the government to stop flooding at Nyabugogo river, it is good to replant bamboo trees and grasses in the areas that they are missing along Nyabugogo river to protect soil erosion and river bank sliding. Placing the gabions at some locations of Nyabugogo river reaches is required in order create a good river landscape in Kigali City. Also, it is suggested to prepare and provide training and awareness programs on environmental matters on surrounding residents. This would help to reduce discharge household wastes in Nyabugogo river and its effluents in order to minimize bottom river sediments deposit which results in excessive floods. Finally, respect and protect buffer-zone along Nyabugogo river to enhance soil resistance to flood. The long-term solution should be to educate children and young people the course of waste management at schools as a solution to environmental pollution.

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Conflict of Interest

The authors declare no conflict of interest.

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